Renewable and Sustainable Energy Reviews 16 (2012) 695–703

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Assessment of Korean customers' willingness to pay with RPS

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ARTICLE INFO

Article history:
Received 7 March 2011
Accepted 25 August 2011
Available online 20 October 2011

Keywords:
Renewable energy
Renewable Portfolio Standard
Willingness to pay
Contingent valuation

ABSTRACT

To increase the use of renewable energy, the Korean government will introduce the Renewable Portfolio Standard (RPS) in 2012. The RPS places responsibility for extra renewable energy costs on the consumers and allows price competition among different renewable sources. Accordingly, this study analyzes through the contingent valuation (CV) the willingness of Korean households to pay more for electricity generated by wind, photovoltaic (PV), and hydropower. Our empirical results show that, although the willingness to pay (or WTP) was highest for wind power and lowest for hydropower, the differences in WTP among the renewable sources were statistically insignificant. This suggests that Korean consumers prefer a renewable portfolio that minimizes power supply costs.

The average WTP for all three energy types was KRW 1562.7 (USD 1.350) per month per household, which was approximately 3.7% of the average monthly electricity bill in 2010. This amount represents only 58.2% of what the Korean government allocated in its budget to the new and renewable energy dissemination program in 2010. Thus, our results imply that the promotion of the new and renewable energy dissemination program may be difficult only with the WTP for electricity generated from renewable sources. Specifically, the mean WTP will not support the set-aside dissemination capacity for PV after 2014.

Contents

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doi:10.1016/j.rser.2011.08.034

1. Introduction

The Korean government intends to increase the share of renewable energy in the overall primary energy mix to 11% by 2030, which would account for approximately 33 million tonnage of oil equivalent (TOE) [1]. To accomplish this, the government has determined that the Renewable Portfolio Standard (RPS) will be implemented by 2012 [2]. The RPS requires each power generating company to include a certain amount of green electricity[1] in its power generation portfolio, an obligation they can satisfy by either owning a renewable energy facility or purchasing green electricity from another company. Thus, the RPS is designed to promote renewable energy in a way compatible with competitive electricity markets [3]. The RPS has been implemented in some countries such as the United States (Wiser et al., 2007) and United Kingdom (Connor, 2003). The Korean government hopes this policy will expand Korea's ratio of green electricity from 2% in 2012 to 10% in 2022. Since the RPS has not yielded a significant diversity of renewable resources, the government established credit multipliers of Renewable Energy Certificates (RECs) for various sources. Moreover, within the RPS' first five years, a set-aside was incorporated for photovoltaic (PV) in hopes of a substantial economic effect. The Korean government expects the RPS to create a market of approximately KRW 49 trillion (USD 42.3 billion)[2,3] by 2022 [2].

The RPS can increase the power generated from renewable sources while creating many social and environmental benefits. Additionally, as the RPS ensures the attainment of a specific market share, it can help achieve a government's policy target for renewable energy dissemination. Berry and Jaccard [4] discuss the effect of the RPS: first, customers eventually pay the extra cost of renewable energy, as the RPS minimizes government involvement; an increased electricity bill can result from a higher generation of green electricity. Second, the RPS offers a perpetual incentive for renewable producers to reduce costs. Thus, price competition among power generating firms can trigger price competition among renewable sources, which may result in an expansion of fiscally advantageous renewable sources.

Most studies have explored the reasons for and effects of the adoption of the RPS [4–6], performed cost analyses of the RPS [7], or calculated the optimal investment portfolio for renewable energy [8]. These studies have thus tended to examine the effects of the policy from the perspective of the government and analyze the costs from the perspective of the power generating companies. However, as the RPS requires the customers to bear the extra expense of renewable energy, it is necessary to consider the issue from their perspective.

To do this, we may refer to previous research on consumer preference for green electricity. Many studies have analyzed the willingness to pay (WTP) for green electricity by applying a contingent valuation (CV). The CV is often used to determine how people value goods for which no market exists [9]. Batley et al. [10] conclude that the green citizen must continue to co-exist with the green power purchaser if any significant improvement in the contribution of renewable energy is to occur. Nomura and Akai [11] investigate the effect on respondents' WTPs of their expectations about the competition between photovoltaic (PV) and wind power. Ek [12] shows that people interested in environmental issues were more likely to be positive about renewable energy. Wiser [13] finds that a collective payment mechanism induced a somewhat higher WTP for green power than a voluntary mechanism did. Both Lee and Hwang [14] and Yoo and Kwak [15] analyze the WTP of Korean households for green electricity, with the former drawing a conclusion that contradicts Ek's [13]. Zografakis et al. [16] show that a higher WTP was reported by those with a higher level of energy information and awareness of climate change.

This paper examines WTPs by applying the CV for electricity generated from wind, PV, and hydropower, which together comprised more than 90% of Korea's green electricity generation in 2008 [17]. We try to answer two research questions. First, do the respondents' WTPs vary with the type of renewable energy? Results indicating that respondents' WTPs are invariant across all types of renewable sources could support the logic of cost minimization from the perspective of the power generating company. Second, is the stated WTP sufficient to meet the financial obligation of renewable energy? To answer this question, we compared the cost of meeting the obligation of renewable energy with the customers' aggregate benefit from it. These results enabled us to determine customers' preferences for certain renewable sources and discover whether the obligation of the RPS can meet the customers' aggregate benefit.

This paper is organized into five sections. Section 2 explains the CV methodology and the questionnaire design. Section 3 provides a description of the data and the respondents' awareness of renewable energy. Section 4 presents and discusses the results, followed by Section 5 with some conclusions.

2. Methodology

2.1. Contingent valuation (CV)

The CV elicits people's preferences for non-market goods (such as public goods) by measuring their WTPs for specified improvements in the goods [18]. This measurement is taken from a direct elicitation of respondents' WTP in monetary terms through carefully designed and administered sample surveys. The CV is often used to examine how people value goods related to renewable energy; the estimated WTP is the maximum amount of money a person will pay in exchange for using green electricity [19].

Following the random utility theory [20], the true indirect utility function denoted as $V(Q, M; S)$ can be defined as Eq. (1). This function describes the maximum amount of utility a household can derive from the level of provision of the non-market good Q and their income M under other demographic and economic factors S. $Z(Q, M; S)$ and ε represent (respectively) the observed indirect utility function and the random variable, which is independent and identically distributed with zero mean.

$$V(Q, M; S) = Z(Q, M; S) + \varepsilon \tag{1}$$

The respondent will decide to accept green electricity by answering "yes" to paying the stated bid amount B if

$$\Delta Z(B) = Z(Q^1, M - B; S) - Z(Q^0, M; S) + \varepsilon_1 - \varepsilon_0 \geq 0 \tag{2}$$

where the state 0 represents non-use of green electricity and the state 1 represents use of green electricity. Eq. (2) can be linearly approximated as

$$\Delta Z(B) = Z(Q^1, M - B; S) - Z(Q^0, M; S) \approx \alpha - \beta B \tag{3}$$

In Eq. (3), α and β, which are expected to have nonnegative values, represent marginal utility from the existence of green electricity and marginal utility of income, respectively [21].

[1] Green electricity in this article refers to electricity generated from renewable energy.

[2] The average standard trading rate (KRW 1157.6 per USD 1), as announced by the Korea Exchange Bank in December 2010, was applied. That is the rate applied in this paper.

[3] The acronyms "KRW" and "USD" mean "South Korean won" and "United States dollar", respectively.

Table 1
Questionnaire type by question order and bid amounts.

Question order	B = KRW 500; B^U = KRW 1000; B^L = KRW 300	B = KRW 1000; B^U = KRW 2000; B^L = KRW 500	B = KRW 2000; B^U = KRW 3000; B^L = KRW 1000
Hydro – PV – Wind	Type 1L	Type 1M	Type 1H
Hydro – Wind – PV	Type 2L	Type 2M	Type 2H
Wind – PV – Hydro	Type 3L	Type 3M	Type 3H
Wind – Hydro – PV	Type 4L	Type 4M	Type 4H
PV – Hydro – Wind	Type 5L	Type 5M	Type 5H
PV – Wind – Hydro	Type 6L	Type 6M	Type 6H

Using Eq. (2), the probability that an individual will answer "yes" to paying B can be converted as the probability that one's WTP will exceed B, and this relationship is given by

$$Pr[\text{"yes"}] = Pr[\Delta Z(B) \geq \varepsilon_0 - \varepsilon_1] = Pr[\text{WTP} \geq B] = 1 - F_{\text{WTP}}(B) \quad (4)$$

where $F_{\text{WTP}}(B)$ denotes a cumulative distribution function of WTP.

To elicit respondents' WTP, this study employed the double-bounded dichotomous-choice (DBDC) approach. It is more efficient than the single-bounded model, as it asks respondents a second dichotomous-choice question that depends on the response to the first question: if an individual i responds "yes" to the first bid (B_i), the second bid (B_i^U) is somewhat greater than the first; however, if the first response is "no," the second bid (B_i^L) is somewhat smaller [22]. Under the DBDC model, the sample can be divided into four possible groups: (a) both answers are "yes"; (b) a "yes" followed by a "no"; (c) a "no" followed by a "yes"; (d) both answers are "no."

Meanwhile, several studies [10,15,16] reported quite high possibilities of zero WTP for renewable energy goods. Therefore, in addition to the conventional DBDC model, we adopted the spike model [23], which allows us to treat zero WTP responses. The spike model assumes that the distribution function of WTP has the following form:

$$F_{\text{WTP}}(B) = \begin{cases} 0 & \text{if } B < 0 \\ p & \text{if } B = 0 \\ G_{\text{WTP}}(B) & \text{if } B > 0 \end{cases} \quad (5)$$

where p belongs to $(0, 1)$ and $G_{\text{WTP}}(B)$ is a right, continuous, and nondecreasing function. We also excluded the case of negative WTP [24].

Thus, when combining the spike and DBDC models, the sample can be divided into five groups. For each individual i, we define the binary valued indicator that tells where the individual belongs among the five groups, such that

$$\begin{aligned} I_i^{YY} &= 1 \quad \text{if WTP} \geq B_i^U (0 \text{ otherwise}) \\ I_i^{YN} &= 1 \quad \text{if } B_i \leq \text{WTP} < B_i^U (0 \text{ otherwise}) \\ I_i^{NY} &= 1 \quad \text{if } B_i^L \leq \text{WTP} < B_i^U (0 \text{ otherwise}) \\ I_i^{NN} &= 1 \quad \text{if } 0 < \text{WTP} < B_i^L (0 \text{ otherwise}) \\ I_i^{0} &= 1 \quad \text{if WTP} = 0 (0 \text{ otherwise}) \end{aligned} \quad (6)$$

Given a sample of N respondents, the log-likelihood function of the above model is given by

$$\begin{aligned} \ln L = \sum_{i=1}^{N} & I_i^{YY} \ln[1 - G_{\text{WTP}}(B_i^U)] + I_i^{YN} \ln[G_{\text{WTP}}(B_i^U) - G_{\text{WTP}}(B_i)] \\ & + I_i^{NY} \ln[G_{\text{WTP}}(B_i) - G_{\text{WTP}}(B_i^L)] + I_i^{NN} \ln[G_{\text{WTP}}(B_i^L - G_{\text{WTP}}(0))] \\ & + I_i^0 \ln[G_{\text{WTP}}(0)] \end{aligned} \quad (7)$$

We assumed a logistic distribution of $G_{\text{WTP}}(B)$, which is expressed as

$$G_{\text{WTP}}(B) = [1 + \exp(\alpha - \beta B)]^{-1} \quad (8)$$

Because α is taken to reflect an individual's socioeconomic characteristics, α can be expressed as

$$\alpha = \sum_{j=1}^{k} \gamma_j X_j \quad (9)$$

where X_j ($j = 1, \ldots, k$) denotes an individual's socioeconomic characteristics.

To estimate α (or γ_j, $j = 1, \ldots, k$) and β, we maximize the log-likelihood function of Eq. (7) under the assumption of Eqs. (8) and (9). Using these estimates, the mean WTP, which should be non-negative, can be computed as follows:

$$\text{WTP} = \frac{1}{\beta} \ln \left[1 + \exp \left(\sum_{j=1}^{k} \gamma_j X_j \right) \right] \quad (10)$$

2.2. Questionnaire design

The questionnaire consisted of three parts [25]. Part A asked a set of attitudinal, behavioral, and lifestyle questions about green electricity and the environment. Part B provided a valuation scenario, value elicitation questions, and some follow-up questions. Part C questioned the socioeconomic and demographic characteristics of the respondents. Questions were selected after reviewing previous studies and conducting brainstorming sessions. To refine the questionnaire, two preliminary surveys were conducted.

The value-eliciting scenario of this study assumed the adoption of the RPS in Korea. The respondents were given a brief introduction to the RPS and were then informed that consumers may have to pay more for their electricity because of it. To determine whether different renewable sources inspire different WTPs, three independent renewable types were mentioned: wind, PV, and hydropower. We said that increases in electricity bills would depend upon the choice of renewable source. After having the value-eliciting scenario explained, respondents were asked sequentially how much more per month they were willing to pay for using power derived from the three different energy sources. This part of the questionnaire included an additional assumption that was made before the WTP-eliciting question was asked: the renewable portfolio consists of only one energy source, not a mix of several renewable sources. This assumption was designed to elicit WTPs for different renewable types independently and therefore does not accurately reflect the actual RPS system. To help the respondents, an explanatory card outlined information on unit-generating costs, each sources' strengths and weaknesses, and photos of each sources.

Mitchell and Carson [18] find that, when valuation questions are asked, respondents' WTPs can be affected by the order in which the goods are arrayed. This problem of sequence bias (or question-order effect) has been mentioned in several papers [26–30]. It arises because of the substitution and income effects: when the bias is operative, the highest WTP is elicited from the initially presented good [30]. We employed three steps to suppress the sequence bias as much as possible. First, enough information on the features of wind, PV, and hydropower were provided [27]. Second, six types of questionnaires, each listing the renewable sources in a different

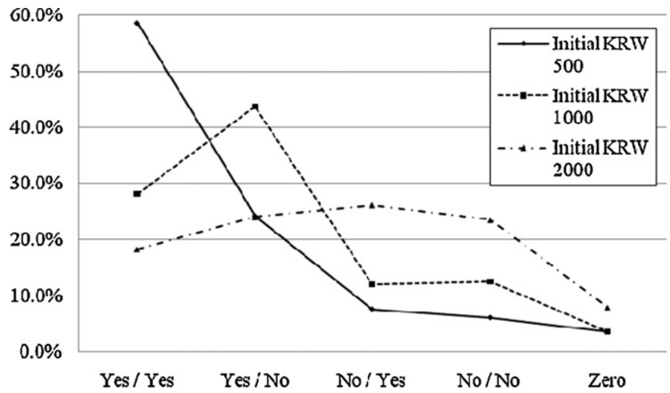


Fig. 1. Answers to WTP eliciting questions for wind power.

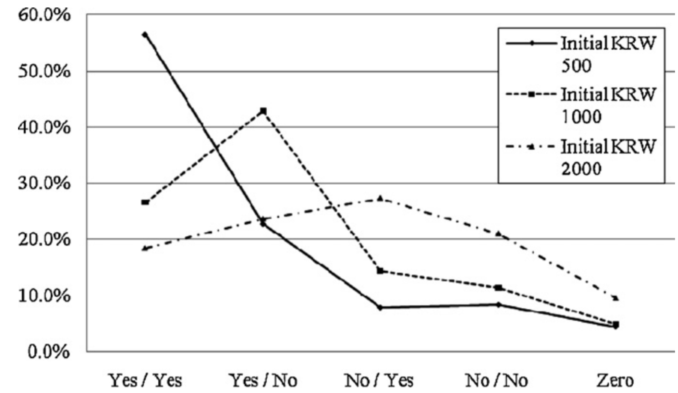


Fig. 2. Answers to WTP eliciting questions for PV.

order, were constructed [28]. Third, before asking the full-fledged value eliciting questions, researchers announced that evaluations for three different renewable sources would be conducted successively [30]. Meanwhile, the bid amount was based on previous Korean studies [14,15] and two sets of pre-surveys. The estimated WTPs of those studies [14,15] are close to the amount of KRW 1500 (USD 1.30), although the values do not perfectly coincide because of the difference in survey periods and estimation models. Thus, three types of bid amounts were selected, and eighteen types of questionnaires were designed, differing in question order and bid amount (Table 1).

To apply the spike model suggested in Section 2.1, respondents who refused to pay at the second stage were given additional questions. The WTPs of the respondents who indicated having no WTP at all can be subdivided into two categories – true zero bids and protest zero bids. True zero bids can be interpreted as a reflection of no increase in utility using green electricity [31]. In contrast, protest zero represents revealed zero WTP, but the true WTP is unknown [32]. The respondents who made protest zero bids are affected by reactions such as being against personal payment for using green electricity or being against the payment vehicles suggested in the questionnaire [33]. Thus, by referring to previous studies [16,32], we provided follow-up questions to distinguish true zero bids from protest zero bids in an attempt to elicit a precise WTP.

3. Data description

3.1. Survey data

The survey took place from August 13, 2010, to September 8, 2010, and covered the entire region of South Korea. Because a monthly electricity bill per household was employed as a payment vehicle, the survey was conducted on heads of households or housewives, aged from 20 to 65. Sampling and fieldwork were carried out by the Korean professional polling firm Dongseo Research, Inc. Following the recommendation of Arrow et al. [9], the survey was conducted via face-to-face interviews led by well-trained interviewers. A total of 720 surveys were conducted with a 100% response rate. None of the questionnaires was found to be inadequate.

The number of respondents who show no WTP at all for wind power, PV, and hydropower was 161, 162, and 153, respectively. To eliminate the protest zero bids, a follow-up question asking why they were not willing to pay for green electricity was presented. Those who insisted that the government should pay any additional cost or that the government was untrustworthy were regarded as making protest zero bids. Through the elimination of respondents with protest zero bids, 588, 595, and 608 respondents were selected for the analysis of WTPs for wind power, PV, and hydropower, respectively.

According to Eq. (6), the answers to value eliciting questions can be categorized into five types (yes/yes, yes/no, no/yes, no/no, zero). Fig. 1 summarizes the responses to dichotomous choices for wind power. The “yes” rate is highest for the bid at KRW 1000 regardless of the initial bid. The rate of those with no WTP at all increases as the initial bid shown to the respondents increases, while a concentration on the specific answer shows the same tendency. The responses to the WTP eliciting questions concerning PV and hydropower show a very similar pattern (Figs. 2 and 3).

3.2. Awareness of renewable energy

Renewable sources are usually more expensive than conventional power generating sources. Therefore, the attitudes toward environmental problems of those respondents willing to pay the additional cost of using renewable energy may influence their WTPs [12,14,16]. Thus, we asked respondents several questions regarding their awareness of renewable energy in part A of the questionnaire.

We asked whether respondents had heard of renewable energy and the RPS; 52.8% answered that they had heard of renewable energy, while only 14.7% had heard of the RPS.

Two questions were then asked to investigate attitudes to environmental problems. The first question probed their attitudes to the effect of energy use for power generation on global warming. Of the respondents, 84.4% described their opinions as “serious” or “very serious” (Fig. 4). The second question asked how much daily effort respondents made to reduce environmental pollution; 64% answered they try “hard” or “very hard” (Fig. 5), suggesting that most of the respondents took the effects of energy consumption on

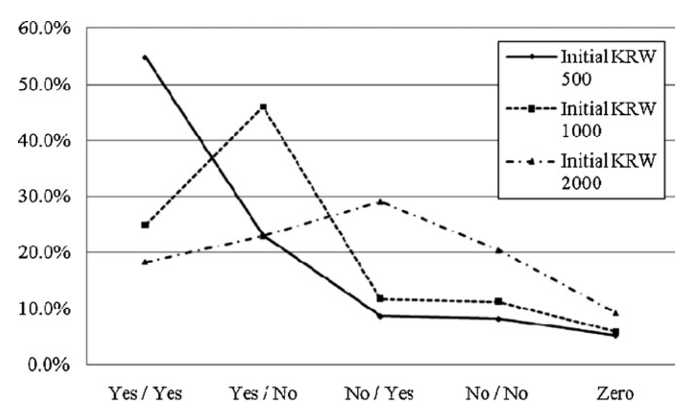


Fig. 3. Answers to WTP eliciting questions for hydropower.

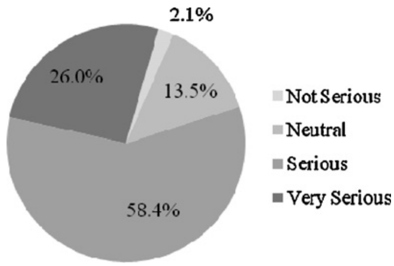


Fig. 4. Attitudes about the effect of energy use for power generation on global warming.

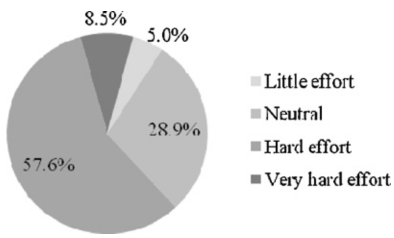


Fig. 5. Level of effort to reduce environmental pollution.

Table 2
Expectations concerning dominant renewable source.

	Wind power	PV	Hydropower	Others
Currently dominant	15.0%	33.9%	50.3%	0.8%
Dominant after 10 years	13.5%	60.6%	24.7%	1.2%
Dominant after 20 years	12.2%	69.0%	17.1%	0.6%

Table 3
Opinion of the strengths and weaknesses of renewable energy.

	Strengths	Weaknesses
Disagree strongly	0.0%	0.3%
Disagree slightly	0.6%	8.1%
Neutral	26.4%	40.3%
Agree slightly	65.8%	50.1%
Agree strongly	7.2%	1.3%

global warming seriously and attempted to minimize their impact on the environment.

We solicited respondents' expectations concerning the competition among renewable energy sources for the present, ten years from now, and twenty years from now. The results in Table 2 show that, although they believed hydropower to be currently dominant, they expected PV to gain dominance in the future. This result indicates that respondents consider PV's potential to be quite high. In fact, hydropower made up 72.6% of Korea's green electricity in 2008 [17], but the Korean government plans to promote the growth of a PV industry [34]. Thus, our respondents seem to have a quite high level of awareness about al leading energy source.

Table 5
WTP differences between renewable sources.

WTP difference	$WTP_W - WTP_P$	$WTP_P - WTP_H$	$WTP_W - WTP_H$
Estimate	35.019	18.499	53.518
Standard error	47.646	47.903	47.646
Wald statistic	0.5408	0.1491	1.2617

The delta method was used to compute estimates for the WTP difference and standard error.
WTP_W, WTP_P, WTP_H, respectively refer to WTP for electricity generated from wind power, PV, and hydropower in this table.
Wald statistic follows χ^2 (1) distribution; χ^2 (1) is 3.842 at the 5% significance levels.

Other questions concerned their views on the strengths and weaknesses of renewable energy. On the strength of renewable energy, 73.0% answered "agree slightly" or "agree strongly." Regarding the weaknesses of renewable energy, more than half of the respondents "agree slightly" or "agree strongly" (Table 3). These results suggest that most respondents are convinced of the strengths of renewable energy.

4. Results and discussions

4.1. Empirical results

The mean WTP estimates for electricity from wind power, PV, and hydropower with RPS are summarized in Table 4. To compute the mean and standard error for WTP, the delta method was applied, enabling the derivation of an approximate probability distribution for a function of an asymptotically normal statistical estimator from knowledge of the limiting variance of that estimator [35]. Table 4 shows that the mean WTP for wind power was highest and that for hydropower was lowest. For all the renewable sources analyzed, the mean WTPs and spikes were statistically significant at the 1% level, and the Wald statistics rejected the null hypothesis that all the parameters are jointly zero. The marginal utility of using green electricity (α) and of income (β) was also significant at the 1% level and showed similarly positive values for all three renewable sources. This implies that the use of green electricity might increase the respondents' utility, while the additional costs of green electricity may slightly lower the respondents' utility. Thus, the results presented in Table 4 are likely in accord with economic theory.

Although respondents believed that hydropower was currently dominant and that PV would become dominant (see Section 3.2), the order of magnitude in the mean WTP was contracted by these expectations. Moreover, the differences in WTP among three renewable were KRW 18.5–53.5 (USD 0.016–0.046), which are very small compared to the differences in power generating cost. Therefore, a test on whether these differences are valid should be conducted. We proposed the null hypothesis that the differences in WTP among renewable sources were statistically insignificant; the result is shown in Table 5. Because the Wald test statistics failed to reject the null hypothesis, we concluded that the differences in WTP

Table 4
Mean WTP estimates by renewable type.

	Wind power	PV	Hydropower
Mean WTP	KRW 1592.2; USD 1.375 (33.4180*)	KRW 1557.2; USD 1.345 (32.5070*)	KRW 1538.7; USD 1.329 (33.1490*)
Wald statistic	1116.7413*	1040.9049*	1098.8802*
Spike	0.07071 (8.4418*)	0.08085 (8.9109*)	0.07926 (8.9337*)
Wald statistic	71.2641*	79.4045*	79.8116*
α	2.5758 (20.2070*)	2.4309 (19.9100*)	2.4524 (20.1730*)
β	0.0017 (22.2340*)	0.0016 (22.3540*)	0.0016 (22.6400)
Observation	588	595	608
Log-likelihood	−788.81	−818.98	−831.81

t-Statistics are described in parentheses.
* Significance at the 1% level.

Table 6
Coefficient estimates of explanatory variables.

Variables	Estimates		
	Wind power	PV	Hydropower
Geography	0.0612 (3.3447*)	0.0527 (2.9078*)	0.0388 (2.1863**)
Age	−0.0708 (−0.7851)	−0.1251 (−1.4147)	−0.1921 (−2.1307**)
Education	0.1459 (0.9598)	0.1787 (1.1941)	0.1263 (0.8631)
Knowledge 1	−0.1526 (−0.9215)	−0.1749 (−1.0665)	−0.2020 (−1.247)
Knowledge 2	−0.1975 (−0.8491)	−0.1786 (−0.7774)	−0.4167 (−1.8003***)
Attitude	0.1084 (0.8959)	0.1816 (1.5269)	0.2466 (2.0800***)
Effort	0.2970 (1.9699**)	0.4009 (2.7519*)	0.5027 (3.4890*)
Expectation 1	−0.0030 (−0.0137)	−0.2392 (−1.4226)	0.2890 (1.8296***)
Expectation 2	−0.2870 (−1.1514)	−0.0590 (−0.2783)	0.0926 (0.4484)
Expectation 3	−0.4024 (−1.5058)	0.2474 (1.1133)	0.1627 (0.7050)
Strength	0.4845 (2.7964*)	0.2476 (1.4496)	0.3345 (1.9663**)
Weakness	−0.4471 (−3.0688*)	−0.3793 (−2.7245*)	−0.4603 (−3.2449*)
Housing type	0.1674 (1.6666***)	0.1043 (1.0485)	0.1689 (1.7268***)
Householder	0.2494 (1.2372)	0.3169 (1.5831)	0.1650 (0.8518)
Early adopter	−0.1666 (−1.8894***)	−0.1865 (−2.1620**)	−0.1974 (−2.2906**)
Bill	−0.0033 (−0.0619)	−0.0450 (−0.8642)	−0.0168 (−0.3211)
Income	0.0888 (1.4774)	0.1116 (1.8909***)	0.1117 (1.8947***)

* Statistical significance at the 1% level.
** Statistical significance at the 5% level.
*** Statistical significance at the 10% level.

Table 7
Unit power generating cost of renewable sources and SMP.

	On-shore wind power	Off-shore wind power	PV	Hydropower	SMP
Unit cost (KRW/kWh)	107.29	160.94	514.99	79.92	118.04

among wind power, PV, and hydropower were negligible. Given this result, respondents seem to have shown almost the same level of WTP regardless of the power generating cost or of expectations regarding the competition among the sources.

Specifically, we employed the model using seventeen explanatory variables to elicit the above mean WTPs (see Table A1 in Appendix A). These variables were related to respondents' awareness of renewable energy and socioeconomic characteristics. The coefficient estimates of these seventeen variables are summarized in Table 6. All coefficient signs were consistent with our expectation except for the coefficients of Expectations 1–3, and the early adopter. The coefficient signs of Expectations 1–3 did not show consistency for each renewable source, and the coefficients for the early adopter were all negative. An explanation for the early adopter's negative estimates may be that respondents more likely to buy new products (such as the latest electronic devices) placed less weight on green electricity; thus, green electricity may not be a preferred good for early adopters.

As mentioned in Section 2.2, a sequence bias can arise in our survey, as it presents successive valuation questions concerning multiple goods. However, the symptom of sequence bias (that the mean WTP for the initially presented good is highest) was not observed (see Table A2 in Appendix B) [30]. To determine conclusively whether sequence bias arose, we tested whether the differences in WTP according to questioning order were insignificant [27,29]. As the null hypothesis was not rejected at the 1% level (see Table A3 in Appendix B), we concluded that a sequence bias did not appear. Therefore, our attempt to avoid sequence bias in the construction of the questionnaire seems to have been effective.

4.2. Discussion

The average WTP for all three renewable types was KRW 1562.7 (1.350 USD) per month per household, approximately 3.7% of the average monthly electricity bill in 2010 [36]. The magnitude of the WTP was not significantly different from of those of [14,15], which examine the Korean WTP for a renewable energy system; the difference among the three survey periods suggests that Koreans' WTP for renewable energy is relatively fixed. Meanwhile, Arrow et al. [9] show that an estimate of the mean WTP could be used to compute the aggregate benefit if respondents were randomly sampled and the response rate of the survey were high enough. As our survey satisfies these conditions, our sample estimates of the WTP can be expanded to the population value. The expanded population value can be drawn by multiplying the annualized WTP estimate per household with the number of national households [37]. This population value suggests that Koreans seem to have a WTP of KRW 321.1 billion (USD 277.4 million) annually for the use of green electricity. This amount is about 58.2% of the Korean government's 2010 budgetary allocation for its new and renewable energy dissemination program [38].

By comparing the expanded population value of the WTP to the extra cost of power generation through renewable energy, we can approximate the ratio of green electricity to total demand for electricity for which consumers are willing to pay more. The unit costs of wind power, PV, hydropower, and the system marginal price (SMP) are needed to calculate the extra cost for generating green electricity [39]. We obtained the unit costs of wind power (both on- and off-shore), PV, and hydropower from the purchase prices of Feed-in-Tariff [40] and the credit multiplier of RECs [41] in Korea. The SMP takes the price of the most expensive scheduled generating unit, except for renewable types; the averaged SMP from January 2010 to August 2010 [42] was used in this study. These values are described in Table 7.

Because the unit costs of on-shore wind and hydropower were lower than the SMP, the additional cost of the expanded use of these types could be disregarded. Nevertheless, the unit costs of off-shore wind and PV power were still higher than the SMP: the additional costs coming from off-shore wind and PV power would be KRW 42.9 kWh^{-1} (USD 0.037 kWh^{-1}) and KRW 396.95 kWh^{-1} (USD 0.343 kWh^{-1}), respectively. Considering that the expanded WTPs per year for PV and wind power were KRW 320.5 billion (USD 276.9 million) and KRW 327.7billion (USD 283.1

Table A1
Explanatory variable descriptions and sample statistics.

Variable	Description	Mean	S.D.
Geography	Respondent's administrative district	6.7361	4.6957
Age	Respondent's age (1–4; 1: twenties, 2: thirties, 3: forties, 4: fifties and sixties)	2.8347	0.9735
Education	Education level of respondent	2.4056	0.6236
Knowledge 1	1 = respondents who have heard of renewable energy 2 = respondents who have never heard of renewable energy	1.4722	0.4996
Knowledge 2	1 = respondents who have heard of RPS 2 = respondents who have never heard of RPS	1.8528	0.3546
Attitude	Attitude to the effect of energy use for power generation on global warming (1–5; 1: not serious at all, 5: very serious)	4.0833	0.6866
Effort	Effort to reduce environmental pollution (1–5; 1: very little effort, 5: very hard effort)	3.8035	0.6323
Expectation 1	Expectation concerning current dominant renewable source (for wind power: wind power = 1, others = 0; for PV: PV = 1, others = 0; for hydropower: hydropower = 1, others = 0)	Wind: 0.1500; PV: 0.3389; hydro: 0.5028	Wind: 0.3573; PV: 0.4737; hydro: 0.5003
Expectation 2	Expectation concerning dominant renewable source after one decade (for wind power: wind power = 1, others = 0; for PV: PV = 1, others = 0; for hydropower: hydropower = 1, others = 0)	Wind: 0.1347; PV: 0.6069; hydro: 0.2472	Wind: 0.3417; PV: 0.4888; hydro: 0.4317
Expectation 3	Expectation concerning dominant renewable source after two decades (for wind power: wind power = 1, others = 0; for PV: PV = 1, others = 0; for hydropower: hydropower = 1, others = 0)	Wind: 0.1222; PV: 0.6903; hydro: 0.1708	Wind: 0.3278; PV: 0.4627; hydro: 0.3766
Strength	Opinion of the strengths of renewable energy (1–5: 1: agree very little, 5: strongly agree)	3.8951	0.5239
Weakness	Opinion of the weaknesses of renewable energy (1–5: 1: agree very little, 5: strongly agree)	3.4233	0.6049
Housing type	1 = detached house, 2 = row house, 3 = apartment	2.2583	0.8372
Householder	1 = no, 2 = yes	1.2417	0.4284
Early adopter	Tendency to buy a new product (1–5; 1: the lowest, 5: the highest)	2.5875	0.9512
Bill	Monthly electricity bill (0–8; 0: do not know, 1: below KRW 10,000, 8: over KRW 70,000)	4.5972	1.5633
Income	Monthly household income (1–10; 1: below KRW one million, 10: over KRW ten million)	5.8306	1.5364

Table A2
Mean WTP estimates based on question order.

	1st questioned	2nd questioned	3rd questioned
Mean WTP	KRW 1544.0 (33.364*)	KRW 1603.1 (33.401*)	KRW 1536.0 (32.258*)
Wald statistic	1113.1425*	1115.6346*	1040.6091*
Spike	0.07568 (8.7230*)	0.07341 (8.6121*)	0.08331 (9.0297*)
Wald statistic	76.0903	74.1683	81.5350
Observation	595	597	599
Log-likelihood	−812.42	−810.70	−821.30

t-Statistics are described in parentheses.
* Significance at the 1% level.

million),[4] respectively, it appears that consumers were willing to pay the costs of an 807 GWh scale PV facility and a 7639 GWh scale off-shore wind power facility, which represent 0.19% and 1.8% of the 2010 electricity demand forecast [43].

Many US states with the RPS have established a set-aside capacity for PV aimed at supporting greater renewable resource diversity and promoting a PV industry [44]. For the same purpose, the Korean government has assigned a set-aside capacity for PV for its first five years under the RPS. Thus, a 346 GWh scale of PV power will be supplied in 2012, increasing gradually to 2074 GWh in 2016. According to our results, Koreans will readily pay the set-aside for PV power until 2013. Beyond that year, however, the additional power generating cost of a PV facility will exceed the consumers' WTP for PV. As mentioned above, the WTP for green electricity does not change significantly; therefore, we can expect that future WTP for PV will not increase significantly. Moreover, it is difficult to assume that an optimistic expectation of PV will result in an increased WTP, as noted in Section 4.2. Therefore, a more prudent policy is needed to adjust a set-aside for PV that adheres to the public's level of WTP as determined by this study.

5. Conclusions

The Korean government will introduce the RPS in 2012. The RPS is a policy tool that provides a continuous incentive for renewable producers to reduce costs and places the extra cost burden of renewable energy onto consumers. Assuming the adoption of the RPS, this paper has investigated the willingness of Korean households to pay more for electricity generated from wind power, PV, and hydropower.

[4] Because we did not distinguish between off-shore and on-shore wind power in the questionnaire, the actual WTP for off-shore wind power may vary.

Table A3
Differences between WTPs based on question order.

WTP difference	$WTP_{1st} - WTP_{2nd}$	$WTP_{2nd} - WTP_{3rd}$	$WTP_{1st} - WTP_{3rd}$
Estimate	59.089	67.025	7.936
Standard error	47.995	47.617	47.617
Wald statistic	1.5157	1.9813	0.0278

WTP_{1st}, WTP_{2nd}, WTP_{3rd}, respectively refer to WTP for 1st, 2nd and 3rd questioned good in this table.
Wald statistic follows χ^2 (1) distribution; χ^2 (1) = 3.841 at the 5% level.

First, our empirical results indicate that the mean WTP for wind power was highest and that for hydropower was lowest; we took care not to generate a sequence bias in eliciting those values. However, the differences in WTP were KRW 18.5–53.5 (USD 0.016–0.046), very small compared to the differences in power generating cost among the three renewable types. Therefore, we tested whether the differences in WTP among wind power, PV and, hydropower were valid; the results failed to reject the hypothesis that these differences were insignificant. This result indicates that the respondents seemed to have almost the same level of WTP regardless of the power generating costs or their expectations concerning the leading renewable source. We thus demonstrate that the respondents' utility did not depend on the type of renewable energy. Our result implies that Korean consumers prefer a renewable portfolio that minimizes the power supply cost.

Second, considering that the average WTP for all three renewable types was KRW 1562.7 (USD 1.350) per month per household, Koreans seemed to have a WTP of KRW 321.1 billion (USD 277.4 million) annually for the use of green electricity. Given that this is about 58.2% of the Korean government's 2010 budget allocation for the new and renewable dissemination program, our result implies that the government's expenditure on the new and renewable dissemination program was higher than consumers' valuation of green electricity. In other words, the promotion of renewable energy dissemination program may be difficult only with the WTP for green electricity. Specifically, we showed that the cost due to the set-aside for PV dissemination would exceed the WTP since 2014.

The implications of our research for policy makers can be summarized as follows. The cost minimization mechanism of the RPS seems to work from the consumers' perspective as well as that of the power generating companies. Thus, an RPS design that minimizes the power supply cost should be employed. Meanwhile, the WTP is unlikely to increase for PV and off-shore wind power under the RPS, and the mean WTP will have ceased to support the set-aside dissemination capacity for PV by 2014.

Acknowledgement

This work was supported by the New and Renewable Energy Program of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea Government Ministry of Knowledge Economy (No. **20093021020020**).

Appendix A. Briefing of the explanatory variables

Seventeen explanatory variables were selected on the basis of the questionnaire. The descriptions and sample statistics of the variables used in the model are reported in Table A1.

Appendix B. Test for sequence bias

To see if sequence bias occurred, we estimated the mean WTP based on the question order and then conducted a statistical analysis. Table A2 shows the results of the average WTP depending on the question order. Table A3 shows the differences between estimated WTPs based on the question order, standard errors, and the Wald test results. The test result in Table A2 fails to reject the null hypothesis; thus, we can conclude that sequence bias in the WTP does not appear.

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